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(54) **CONNECTING ROD INCORPORATING AN ENERGY ABSORBER**

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B64C 1/06	(2006.01)
F16F 1/00	(2006.01)
F16F 9/00	(2006.01)
F16F 9/32	(2006.01)
F16F 9/58	(2006.01)

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(58) **Field of Classification Search**

CPC F16F 7/12; F16F 7/123; F16F 7/128; F16F 9/003; F16F 9/3207; F16F 9/346; F16F 9/36; F16F 9/54; F16F 9/58

USPC 188/371, 377; 267/70, 71, 72, 73, 74; 166/242.7, 381, 169, 178

See application file for complete search history.

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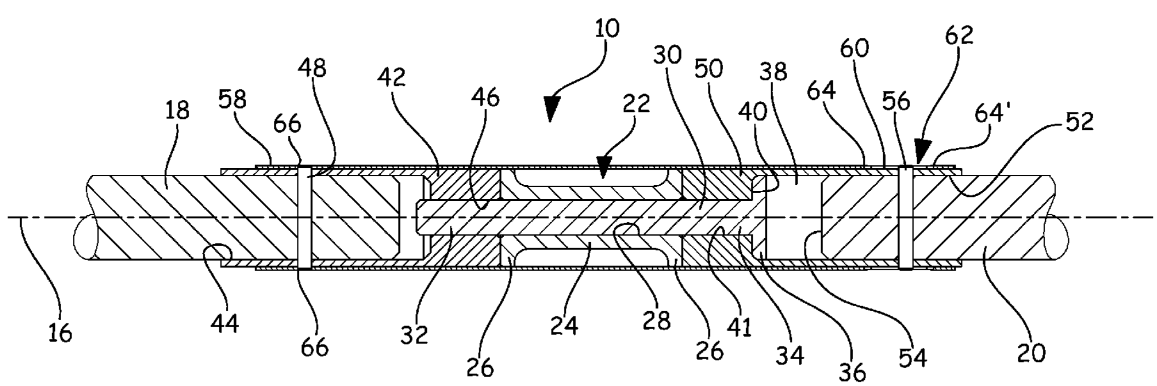
(57) **ABSTRACT**

A connecting rod including two non-connected rod elements coaxial with a longitudinal axis which are offset along the longitudinal axis, and an energy-absorption device that absorbs energy by plastic deformation. The energy-absorption device includes a coaxial hollow tube with a wall which deforms plastically when subjected to an axial compressive force exceeding a certain threshold, a coaxial pin having ends immobilized with respect to the rod elements in the event of tensile forces, and a sleeve fitting over the two facing ends of the rod elements which are positioned one on each side of the energy-absorption device, the sleeve being slidable with respect to one rod element in order to allow the hollow tube and/or the pin to deform and absorb energy. The sleeve limits a range of deformation so that a breaking point of the energy-absorption device is not reached.

6 Claims, 3 Drawing Sheets



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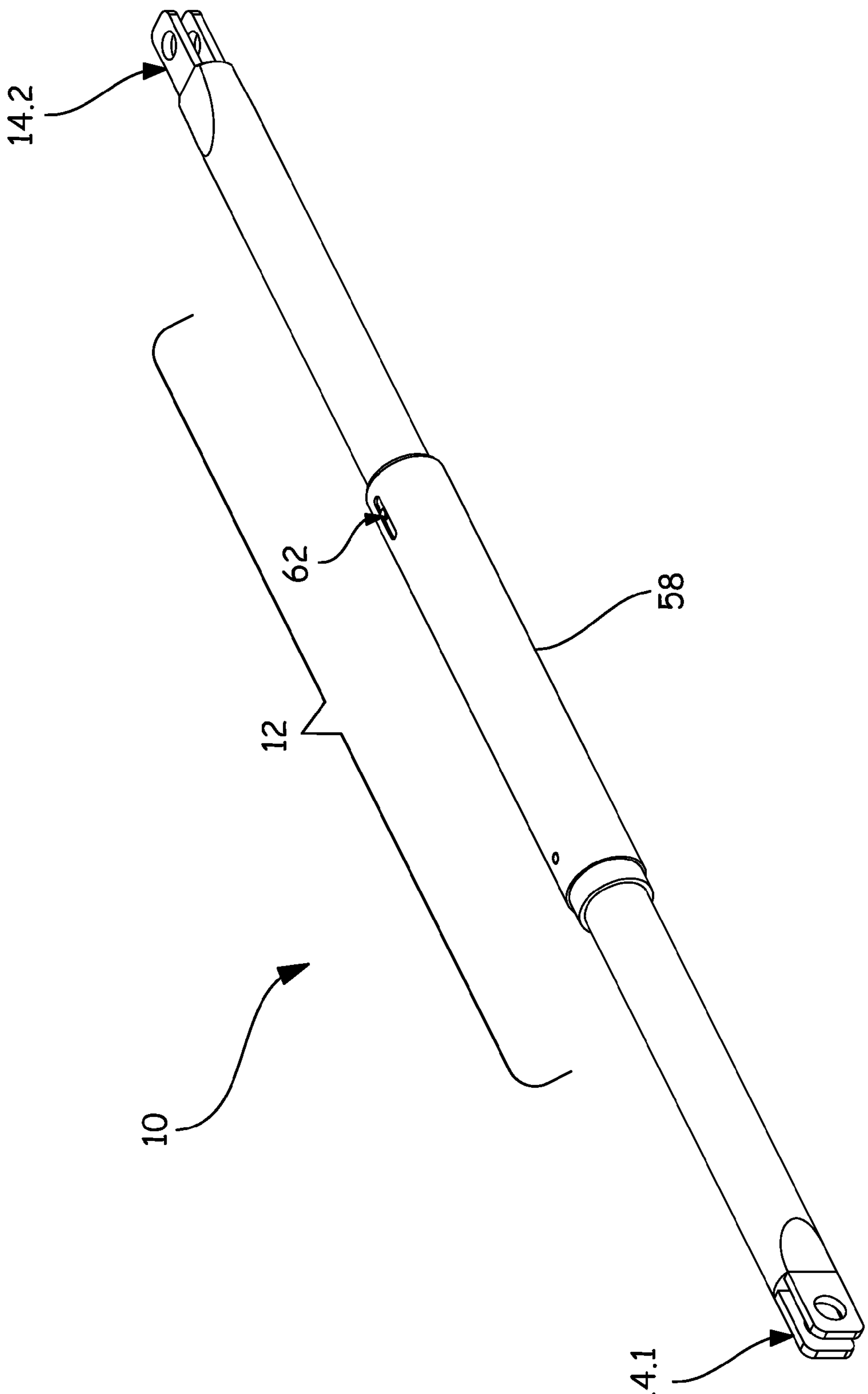

Fig.1

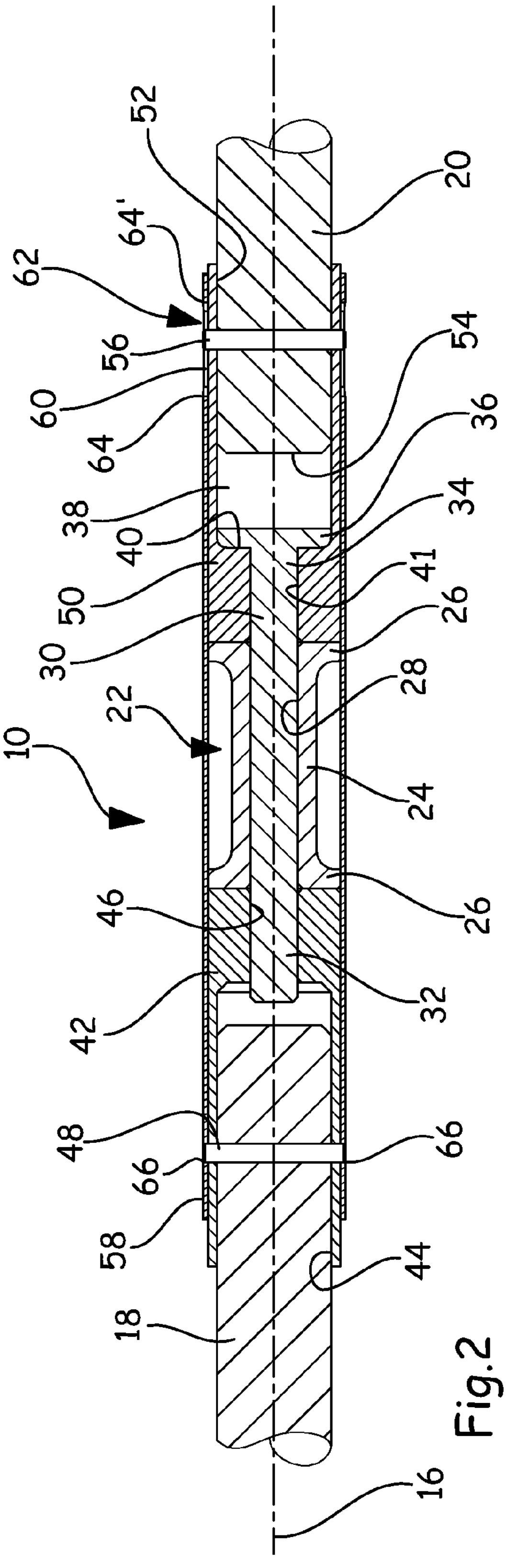
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Fig.2

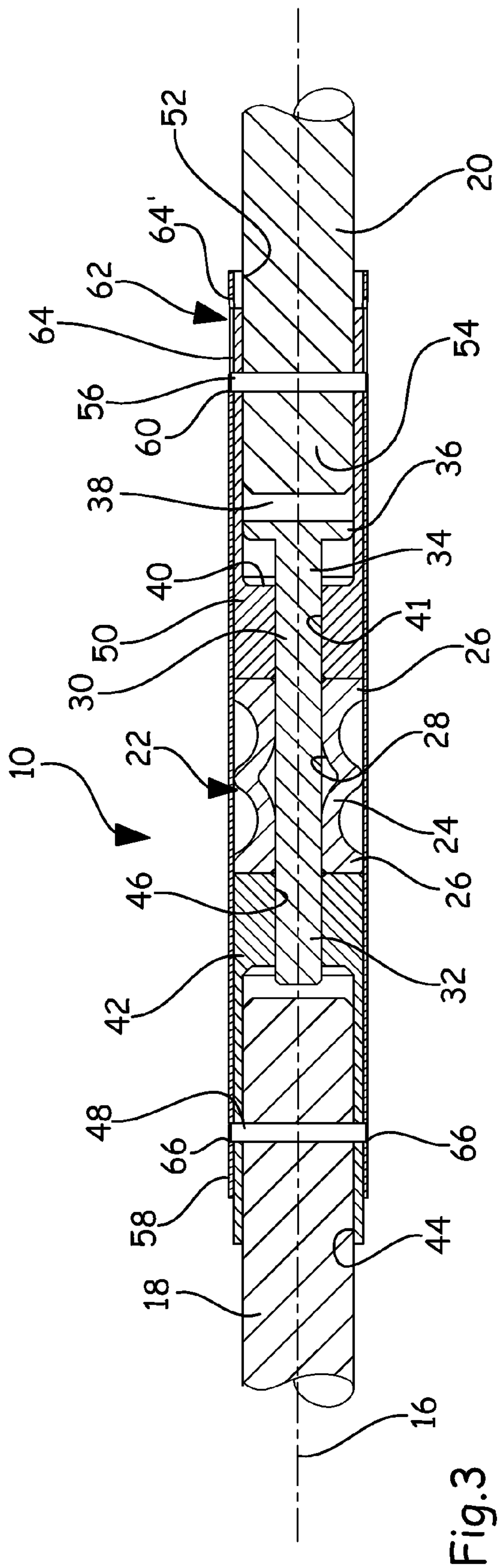
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Fig.3

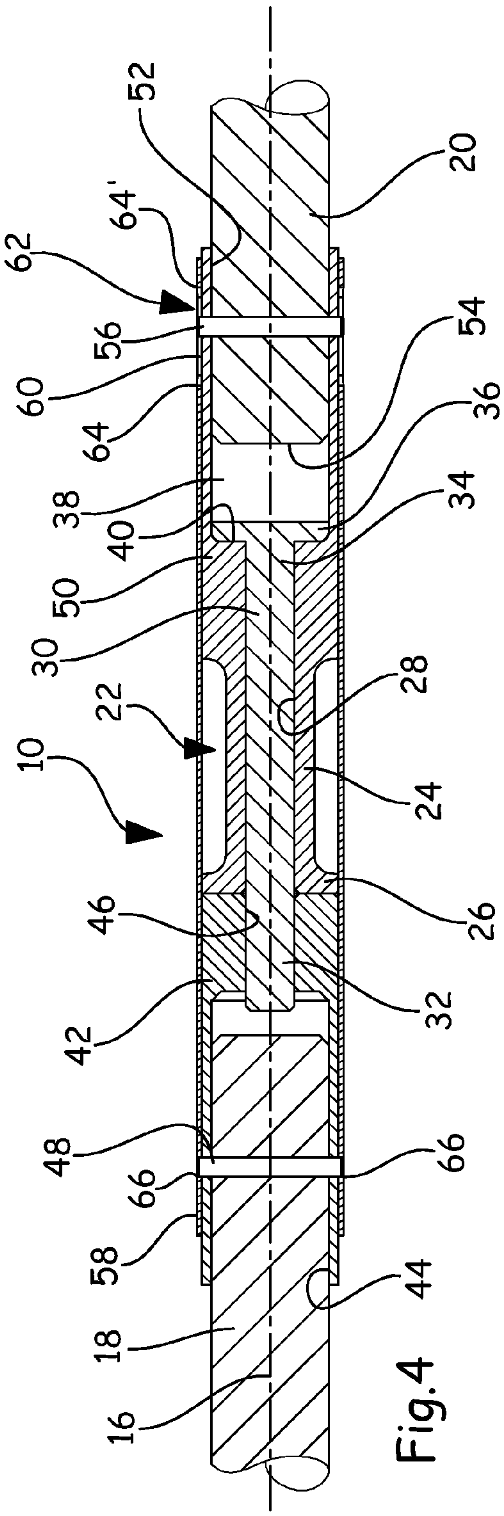
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Fig.4

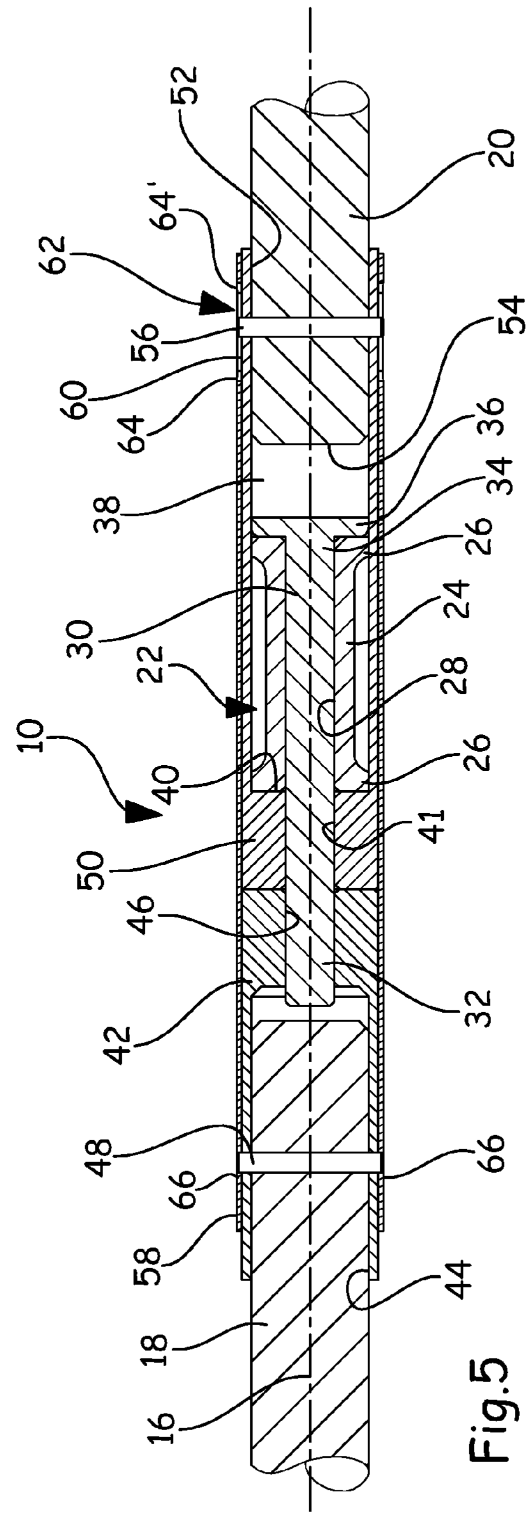
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Fig.5

CONNECTING ROD INCORPORATING AN ENERGY ABSORBER

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims the benefit of the French patent application No. 12 56318 filed on Jul. 2, 2012, the entire disclosures of which are incorporated herein by way of reference.

BACKGROUND OF THE INVENTION

The present invention relates to a connecting rod incorporating an energy absorber.

Many connecting rods are used in an aircraft to connect two parts and allow force to be transmitted between the two connected parts. These connecting rods may be made of metal or of composite.

In the known way, a connecting rod comprises a longilinear body, for example, cylindrical, with, at each end, a head that allows the connecting rod to be connected to an element.

From a functional standpoint, a connecting rod allows two elements to be connected while maintaining a constant distance between them and allowing force to be transmitted between the two connected elements.

Connecting rods are engineered to react forces during normal operation and also in the event of accidental dynamic loading. In the latter instance, a connecting rod does not filter out some of the energy but transmits it in full from one end to the other which means that the elements connected need to have a structure that is reinforced in the region of the connection to the connecting rod. This reinforcing of the structure leads to an increase in the amount of weight carried and therefore to an increase in the energy consumption of the aircraft.

By way of example, an aircraft engine fan is positioned in a duct connected to the rest of the structure of the nacelle by a number of connecting rods referred to as thrust rods, illustrated for example in document FR-2,806,699. Should a fan blade break, the energy stored by the blade tends to deform the duct and to spread towards the structure of the nacelle along the connecting rods.

Depending on the material used, a connecting rod can deform in the plastic domain in buckling and absorb some of the energy in the event of accidental dynamic loading.

While this type of energy absorption is possible with metal connecting rods, it is not possible in connecting rods made of composite material which are unable to deform in the plastic domain in buckling.

In addition, although this type of deformation in the plastic domain in buckling is possible when the connecting rods are made of metal, it causes a significant relative movement between the heads of the connecting rod and this is generally detrimental to the structure of the nacelle or of the aircraft.

SUMMARY OF THE INVENTION

Hence, the present invention seeks to remedy the disadvantages of the prior art by proposing a connecting rod with an energy absorber that makes it possible to limit the spread of at least a significant portion of the energy.

To this end, the subject of the present invention is a connecting rod comprising two rod elements which are coaxial with a longitudinal axis, are non-connected and are offset along the longitudinal axis, and an energy-absorption means

that absorbs energy by plastic deformation, characterized in that the energy-absorption means comprises:

- a hollow tube with an axis coaxial with a longitudinal axis and the wall of which is able to deform plastically in buckling when the hollow tube is subjected to a compressive force directed in the direction of the longitudinal axis, and exceeding a certain threshold,
- a pin, coaxial with the longitudinal axis, the ends of which are immobilized with respect to the rod elements in the event of tensile forces,
- a sleeve which fits over the two ends of the rod elements which are positioned one on each side of the energy-absorption means and which is able to slide with respect to one rod element in order to allow the hollow tube and/or the pin to deform and to act as an energy absorber, the said sleeve making it possible to limit the range of deformation so that the breaking point of the energy-absorption means is not reached.

Thanks to this design of the connecting rod, it is possible to limit the spread of energy.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages will become apparent from the description of the invention which will follow, which description is given merely by way of example with reference to the attached drawings, in which:

FIG. **1** is a perspective view of a connecting rod according to the invention,

FIG. **2** is a longitudinal section through a connecting rod according to the invention prior to deformation,

FIG. **3** is a longitudinal section through the connecting rod illustrated in

FIG. **2** after deformation,

FIG. **4** is a longitudinal section through a connecting rod according to another variant of the invention, and

FIG. **5** is a longitudinal section through a connecting rod according to another variant of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** depicts as **10** a connecting rod with a longilinear central part **12** having at each of its ends, a head **14.1** or **14.2** that provides the connection between the connecting rod **10** and an element that has not been depicted.

The connecting rod may or may not be adjustable for length, depending on the circumstances.

The heads **14.1** and **14.2** of the connecting rod and any length-adjustment means that might be present are not described further because these are known to the person skilled in the art.

In the remainder of the description, the longitudinal direction means the direction corresponding to the longest dimension of the connecting rod. In FIGS. **2** to **5** it corresponds to the longitudinal axis reference **16**.

A longitudinal plane contains the longitudinal direction whereas a transverse plane is perpendicular to the said longitudinal direction. A radial direction is perpendicular to the longitudinal direction.

The connecting rod **10** comprises a first rod element **18** connected to the first head **14.1** and a second rod element **20** connected to the second head **14.2**, the two rod elements **18** and **20** being coaxial with the longitudinal axis **16**, non-connected and offset along the longitudinal axis **16**. These rod elements **18** and **20** may be made of a composite material.

According to one specific feature of the invention, the connecting rod comprises an energy-absorption means **22** that absorbs energy by plastic deformation and is interposed between the two rod elements **18** and **20**. This energy-absorption means **22** comprises a hollow tube **24** with an axis coaxial with the longitudinal axis **16**. The material used for the hollow tube **24**, the wall thickness of the hollow tube **24** and the diameter thereof are tailored so that the wall of the hollow tube buckles when the hollow tube is subjected to a compressive force directed in the direction of the longitudinal axis **16**, that exceeds a certain threshold.

In the remainder of the description, compressive forces mean forces parallel to the longitudinal axis **16** and directed towards one another. Tensile forces mean forces parallel to the longitudinal axis **16** and directed in such a way as to stretch the connecting rod.

When the compressive forces experienced by the hollow tube **24** are below a given threshold, the hollow tube **24** does not deform. When the connecting rod experiences a dynamic load which induces compressive forces on the hollow tube that exceed the given threshold, the hollow tube **24** deforms in the plastic domain and absorbs some of the energy produced by the compressive forces.

As it deforms, the diameter of the median part of the wall of the hollow tube **24** tends to expand in a transverse plane and the ends of the hollow tube tend to move closer together in the longitudinal direction, as illustrated in FIG. **3**.

Unlike in the prior art, the absorption of energy gives rise to only a small relative movement between the two heads which movement is not detrimental to the structure of the aircraft incorporating such a connecting rod.

According to another advantage, a connecting rod, the rod elements **18** and **20** of which are made of composite, can act as an energy absorber if an energy-absorption means **22** according to the invention is incorporated.

For preference, the hollow tube **24** works in compression then in buckling. The material is chosen to achieve a compromise between the elastic limit in compression, the elastic limit at breakage and price. According to one embodiment, the hollow tube **24** is made of steel type E-Z5CNU15-05 (15-5PH).

The length of the hollow tube **24** may be tailored notably according to the amount of energy absorption required. In addition, the wall of the hollow tube may have shapes or machining that allow the hollow tube to deform in a wave (or a ripple) as illustrated in FIG. **3**, or in several waves (several ripples) depending notably on the amount of energy that is to be absorbed.

For preference, the hollow tube **24** has a flange **26** at each end. Thus, the hollow tube **24** comprises a bore **28** with a constant inside diameter extending in the longitudinal direction and passing right through it. On the outside, the tube has an outside diameter De over its length with the exception of the flanges **26** the outside diameter Dc of which is greater than De. The flanges **26** allow better reaction of force by increasing the cross section of the ends of the hollow tube **24**.

Advantageously, the energy-absorption means **22** comprises a pin **30**, coaxial with the longitudinal axis **16** on which the hollow tube **24** is mounted, it being possible for the pin **30** to move in a translational movement in the direction of the longitudinal axis with respect to at least one of the two rod elements **18**, **20**. This pin allows the hollow tube **24** to be centered with respect to the said rod elements **18** and **20**.

According to one embodiment, the outside diameter of the pin **30** is substantially equal, disregarding clearances, to the inside diameter of the hollow tube **24**. This arrangement allows the hollow tube to be kept coaxial with the longitudinal axis **16**.

The pin **30** extends all the way through the hollow tube **24** so that one of its ends **32** collaborates with the rod element **18** while the other end **34** collaborates with the rod element **20**.

According to one feature of the invention, the pin **30** acts as an energy absorber in the event of dynamic loadings producing tensile forces.

In this variant, one of the ends **32** of the pin **30** is secured to one rod element **18**. In one embodiment, the end **32** of the pin **30** is threaded and screws into a tapped hole secured to the rod element **18**.

To complement this, the other end of the pin **30** comprises a head **36** the diameter of which is greater than the diameter Da of the pin **30** and able to be accommodated in a cylindrical cavity **38** secured to the second rod element **20**, coaxial with the longitudinal axis **16**, the inside diameter of which cavity is slightly greater than the diameter of the head **36**. This cylindrical cavity **38** comprises at least one terminal face **40** perpendicular to the longitudinal axis **16**, directed towards the first rod element **18**, said cavity being extended in the direction of the first rod element **18** by a passage **41** the inside diameter of which is matched, disregarding clearances, to the diameter Da of the pin **30** and less than the diameter of the head **36**. In the non-deformed state the head **36** bears against the terminal face **40**. In the event of tensile forces, the two ends of the pin **30** are immobilized with respect to the rod elements **18** and **20** so that the pin has a tendency to be stretched.

In this variant, as illustrated in FIGS. **2** to **4**, the hollow tube **24** is interposed between the ends of the rod elements **18** and **20**. In this case, the absorption means **22** is a two-way means and absorbs both compressive forces via the hollow tube **24** and tensile forces via the pin **30**.

The pin **30** is engineered and made from a material that allows it to deform plastically as it lengthens.

For preference, the pin **30** is made of a material which has an elongation at breakage of between 10 and 40% depending on the material used and on the stated requirement.

According to one embodiment, the pin **30** is made of a material marketed under the trade name Nimonic.

According to another variant illustrated in FIG. **5**, the hollow tube **24** may be positioned between the head **36** of the pin **30** and the terminal face **40** of the cylindrical cavity **38**. In that case, because the pin **30** is secured to the first rod element **18**, the absorption means **22** is a one-way means and absorbs only tensile forces.

The two-way variant is favored because connecting rods are generally dynamically stressed with oscillatory phenomena which have a tendency initially to generate compressive forces and then to generate tensile forces.

Advantageously, at least one of the two rod elements **18**, **20** of the connecting rod comprises a means of connection to the absorption means **22**.

According to one embodiment, the first rod element **18** comprises an end-piece **42** that provides the connection between the rod element **18** and the energy-absorption means **22**. This end-piece **42** of cylindrical shape comprises at a first end a cylindrical housing **44** the inside diameter of which is matched, disregarding assembly clearances, to the outside diameter of the first rod element **18** and, at the other end, a tapped hole **46** into which the pin **30** can be screwed. The connection between the end-piece **42** and the rod element **18** is provided by any suitable means, notably using a stop pin **48** arranged in a transverse plane which passes through the end-piece **42** and the rod element **18**.

According to one embodiment, the second rod element **20** comprises an end-piece **50** providing the connection between the energy-absorption means **22** and the second rod element **20**.

This end-piece **50** of cylindrical shape comprises at a first end a cylindrical housing **52** the inside diameter of which is matched, disregarding the assembly clearances, to the outside diameter of the second rod element **20**. This housing **52** has a closed end perpendicular to the longitudinal axis **16** (which corresponds to the terminal face **40** of the cylindrical cavity **38**) and which is distant from the end **54** of the second rod element **20** so as to delimit the cylindrical cavity **38**. The end-piece **50** also comprises a passage **41** through which the pin **30** can pass.

The connection between the end-piece **50** and the rod element **20** is afforded by any suitable means, notably using a stop pin **56** arranged in a transverse plane which passes through the end-piece **50** and the rod element **20**.

According to the variant illustrated in FIGS. **2** to **3**, the hollow tube **24** and the end-piece **50** may be two separate components. According to the variant illustrated in FIG. **4**, the hollow tube **24** and the end-piece **50** can be one single component.

According to one feature of invention, the connecting rod comprises a sleeve **58** which fits over the two ends of the rod elements **18** and **20** which are positioned one on each side of the energy-absorption means **22**, more specifically over the end-pieces **42** and **50** in order to join these together.

This sleeve **58** makes it possible to obtain a surface that is approximately cylindrical.

According to one embodiment, the sleeve **58** has an inside diameter equal, disregarding assembly clearances, to the outside diameter of the end-pieces. This arrangement makes it possible to limit the risks of the rod elements and of their end-fittings deforming in buckling in the region of the energy-absorption means **22**.

According to one feature of the invention, the sleeve **58** can slide with respect to a rod element or with respect to an end-piece (the end-piece **50** according to the example illustrated) so as to allow the hollow tube **24** and/or the pin **30** to deform and act as an energy absorber. Advantageously, the translational travel of the sleeve **58** with respect to the end-piece **50** is limited. According to one embodiment, the sleeve **58** comprises an oblong hole **60** capable of accommodating an end stop **62** secured to the end-piece **50** or to the rod element **20** with respect to which the sleeve **58** can slide. Thus, this end stop **62** makes it possible to limit the plastic deformation of the energy-absorption means **22** before it breaks by bearing against one of the ends **64** or **64'** of the oblong hole **60**. The dimensions of the oblong hole and, more particularly, the length thereof and the position of the end stop **62** with respect to the ends **64**, **64'** are determined according to the absorption capability of the energy-absorption means and according to the direction of the energy that is to be absorbed.

In the case of a two-way energy-absorption means **22**, the end stop **62** is positioned at equal distances from the ends **64** and **64'**.

According to one embodiment, the sleeve comprises two oblong holes **60** arranged symmetrically and in which the ends of the stop pin **56** which act as end stops **62** can be accommodated. To hold the sleeve **58** in place with respect to the other end-piece **42**, the sleeve **58** comprises two cylindrical holes **66** in which the ends of the stop pin **48** can be accommodated, the cylindrical holes **66** having a diameter equal, disregarding assembly clearances, to that of the stop pin **48**.

Advantageously, the connecting rod comprises means to encourage sliding between the component parts capable of sliding relative to one another, such as the pin **30** with respect to the end-piece **50** and the sleeve **58** with respect to the end-piece **50**. According to one embodiment, self-lubricating bushings are interposed between those component parts which slide relative to one another.

The assembling of the connecting rod is now described.

The end-piece **50** and the hollow tube **24** are slipped over the pin **30**, the head **36** of the pin being positioned in the housing **52** of the end-piece. Next, the end **32** of the pin **30** is screwed into the tapped hole **46** of the end-piece **42**.

The sleeve **58** is fitted over the end-pieces **42** and **50**. Next, the end of the first rod element is introduced into the housing **44** of the end-piece **42** then the stop pin **48** is fitted. The end of the second rod element **20** is introduced into the housing **52** in the end-piece **50** then the stop pin **56** is fitted taking care to position it at equal distances from the ends **64**, **64'** of the oblong hole **60**.

As indicated earlier, the dimensions, shapes and material of the hollow tube **24** are determined according to the maximum compressive load that the connecting rod can withstand.

In the case of a two-way energy-absorption system, the dimensions, shapes and material of the pin **30** are determined according to the maximum tensile loading that the connecting rod can withstand.

The length of the oblong hole **60** and the position of the end stop **62** with respect to the ends of the oblong hole are determined in such a way as to allow relative movement between the two rod elements and plastic deformation of the hollow tube **24** and/or of the pin **30**.

To prevent the energy-absorption means **22** from breaking, the end stop **62**, the sleeve **58** and more particularly the thickness thereof, and the dimension of the oblong hole **60** are determined in such a way as to ensure that the forces can be reacted and breakage of the absorption means **22** avoided.

If the connecting rod is subjected to dynamic compressive loading, the rod elements **18** and **20** will move closer together and compress the hollow tube **24**. The latter will deform plastically and thus absorb some of the energy so that not all of the energy will be transmitted from one end to the other.

In the event of dynamic loading of oscillating type (reverse cycle compressive/tensile loading), the rod elements **18** and **20** will first of all move closer together and compress the hollow tube **24**, which will deform and absorb some of the energy. In a second phase, the rod elements **18** and **20** will tend to move apart and stretch the pin **30** which will deform and absorb some of the energy. Conversely, the dynamic loading may comprise a tensile phase followed by a compressive phase.

In either or both instances, the connecting rod comprises means in the form of at least one end stop **62** to limit the range of deformation so that the breaking point of the energy-absorption means (hollow tube **24** and/or pin **30**) is not reached.

As is apparent from the foregoing specification, the invention is susceptible of being embodied with various alterations and modifications which may differ particularly from those that have been described in the preceding specification and description. It should be understood that I wish to embody within the scope of the patent warranted hereon all such modifications as reasonably and properly come within the scope of my contribution to the art.

The invention claimed is:

1. A connecting rod comprising two rod elements which are coaxial with a longitudinal axis, are non-contacting and are offset along the longitudinal axis, and an energy-absorption means that absorbs energy by plastic deformation, wherein the energy-absorption means comprises:

a hollow tube with an axis coaxial with the longitudinal axis and with a wall which is able to deform plastically in buckling when the hollow tube is subjected to a compressive force directed in the direction of the longitudinal axis, and exceeding a certain threshold,

a pin, coaxial with the longitudinal axis, each axial end of the pin being limited in displacement away from a respective one of the rod elements in the event of tensile forces applied to the connecting rod,

a sleeve fitting over the two facing axial ends of the rod elements which are positioned one on each side of the energy-absorption means, the sleeve being able to slide with respect to one rod element in order to allow at least one of the hollow tube and the pin to deform and to act as an energy absorber, the sleeve making it possible to limit a range of deformation of the energy absorption means so that a breaking point of the energy-absorption means is not reached, wherein the sleeve comprises an oblong hole capable of accommodating an end stop secured to at least one of the two rod elements with respect to which the sleeve can slide.

2. The connecting rod according to claim **1**, wherein the pin is able to deform plastically in the event of tensile forces applied to the connecting rod and directed in the direction of the longitudinal axis.

3. The connecting rod according to claim **1**, wherein the pin comprises a first end secured to a first rod element and a second end with a head accommodated in a cylindrical cavity secured to the second rod element and extended in a direction of the first rod element by a passage to allow the pin to pass, the cavity having at least one terminal face directed towards the first rod element against which the head of the pin bears in a non-deformed state of the energy-absorption means.

4. The connecting rod according to claim **2**, wherein the pin is made of a material which has an elongation at breakage of between 10 and 40%.

5. The connecting rod according to claim **1**, wherein the hollow tube has a flange at each end.

6. The connecting rod according to claim **1**, wherein the two rod elements comprise a first rod element and a second rod element; the connecting rod comprises an end-piece comprising a housing for the second rod element and a stop pin providing the connection between the end-piece and the second rod element, the end of the stop pin being accommodated in the oblong hole of the sleeve so as to act as the end stop.

* * * * *